EVALUATION OF A BMA k2300r CONTINUOUS CENTRIFUGAL AT UBOMBO MILL, SWAZILAND

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Abstract

A high grade continuous centrifugal was commissioned at Ubombo sugar factory in Swaziland in 2007. The performance of the machine was evaluated and compared against the design specification. Results of experiments and the operational experiences are reviewed.

Continuous centrifugation for A-massecuite producing refinery melt is a relatively new concept which has not been widely implemented in sugar processing. It was thus imperative to explore this concept by evaluating its performance. The continuous centrifugal BMA k2300r also has A-molasses classification as designed by the manufacturer. This paper shows how the centrifugal was evaluated and the success of the installation.

Keywords: continuous centrifugal, refinery melt, A-massecuite, classification

Introduction

New centrifugal installations in the sugar industry are based on the known performance of the existing equipment or the anticipated (newer design) performance of the new equipment. This was the case at Ubombo sugar factory in Swaziland in 2007 when installing, commissioning and operating a new design BMA k2300r continuous A-centrifugal for producing refinery melt. This is a molasses classification centrifugal processing A-massecuite on the A-station.

The design parameters for the BMA k2300r centrifugal are listed in Table 1.

Table 1. Design parameters for the BMA k2300r centrifugal.

Massecuite rate	32 ton/h
Purity rise	≤ 2.50
Dry solids content	70%
Wash water % to massecuite	6-8%

A number of tests were conducted to evaluate the centrifugal. The results and findings of this study are discussed in this paper.

Design

The continuous centrifugal is of the vertical type as shown in Figure 1. Its basket is driven from below through a balanced-tension V-belt transmission by an external AC motor. All rotating components are located within the centrifugal housing. The totally enclosed housing and feeding system prevent ingress of cold air and so improve the separation process. All machine components that come into contact with massecuite are supplied in stainless steel. The material used is a very high tensile strength steel that is resistant to stress corrosion, and also has a particularly high resistance to chlorine ions.

The housing has a large removable screw on the cover that provides free access to the inside of the machine. In addition, a practical inspection door allows easy access to the inside of the machine and facilitates easy replacement of the working screens. A tight seal between the upper basket edge housing cover and an external ring pipe prevent melting medium from entering the molasses compartment and mixing with the molasses.

The centrally located product distributor surrounds the bearing assembly, which extends into the basket. The feeding system projecting into the distributor is provided with steam and water connections for massecuite pre-treatment. For additional water supply, the basket incorporates a washing facility. A flow meter fitted in the water supply pipe indicates the quantity of the water added.

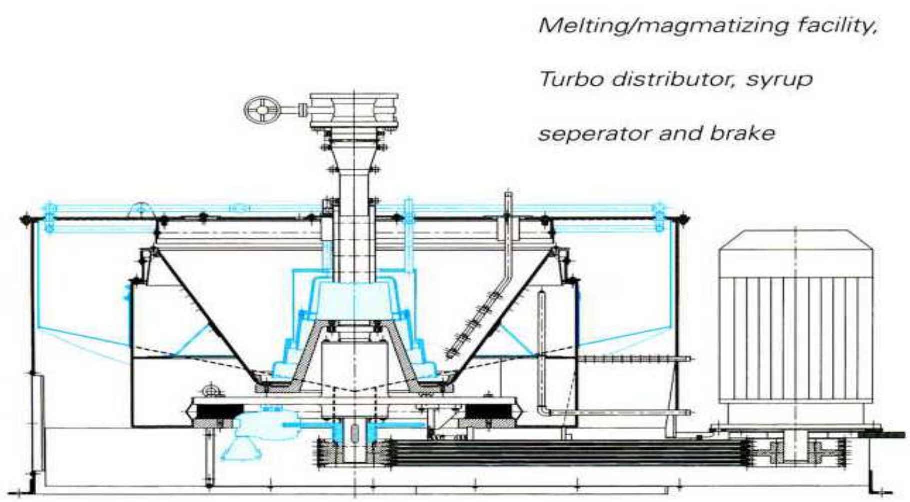

Figure 1. Schematic drawing of BMA k2300r continous centrifugal.

The design of the backing screen ensures unobstructed removal of molasses and provides optimum support for the working screen. A basket angle of 30^o allows optimum separation by merely adjusting the basket speed.

Special buffer rubbers fitted between the bearing housing flange and the housing bottom, as well as favourably located centres of gravity of all rotating components in respect of the bearing assembly and the V-belt tension balancing device, ensure a smooth and steady running centrifugal (www.BMA.com, accessed 01 November 2009).

Massecuite, water and steam continuously enter the machine's product distributor through the feeding system. The distribution cup mixes these thoroughly, and this pre-treated feed stream is then uniformly spread and accelerated. The massecuite leaves the product distributor and moves on to the screen clamping ring in the lower area of the basket. From here the massecuite flows evenly on to the basket's working screen.

Wash water is applied to the moving layer of crystals via a water washing facility. Under action of centrifugal force the washed crystals move over the top of the basket into the sugar compartment, where the sugar is melted by a melting facility and transported through the melt line outlet.

The centrifugal is also equipped with an efficient molasses separator. The molasses separation is essential for processing high grade massecuites.

Operating experiences as specified by manufacturer

The BMA k2300r has proved easy to operate, with a high mechanical reliability which translates into higher machine availability. The machine is equipped with a programmable logic controller (PLC) control screen where the operator manipulates the feed, wash water, and steam valves to the centrifugal. The machine loading can be controlled in two ways; (i) by setting a constant massecuite feed (set the massecuite valve) and adjusting the water quantity to give the right sugar purity, or (ii) by maintaining constant water quantity and adjusting the massecuite rate to give the required sugar purity. It is up to the operator to determine the settings required to manage throughput and quality.

Evaluation of BMA k2300r continuous A-centrifugal at Ubombo

Background

Continuous centrifugation of high grade massecuite is a relatively new concept in the sugar industry, with a narrow margin of implementation in raw or refined sugar. Recently, the implementation trend is widening, mainly due to the economic advantage of lower maintenance costs, lower capital costs and reduced operator attention required. Such advantages led Illovo Sugar to install a BMA k2300r continuous machine at Ubombo Mill, Swaziland.

The continuous A-centrifugal providing sugar for the back-end refinery was installed in parallel with the existing batch A-centrifugals and a BMA k1500 continuous machine. It has a separate A-massecuite feed line from the last A-bank of crystallisers. This is a molasses classification machine which has separate lines for high and low purity molasses, which drain into separate tanks. The machine also has a separate line for the sugar which drains into an A-sugar remelter (refinery melter).

The molasses is separated by an efficient syrup separator, a device that allows the centrifugal to produce two types of molasses that differ in purity and are processed separately. The molasses classification involves separating the high and low purity molasses from the centrifugal and diverting the high purity fraction to the syrup (for the A-pan feed). The high purity molasses is expected to have purity above or equal to the evaporator syrup purity. By diverting the high purity molasses to syrup, lower purity A-molasses is available as feedstock for making B-massecuite. Low purity B-molasses is subsequently produced, which in turn provides the opportunity to reduce the purity of the C-strike. This in turn decreases the final molasses purity, which maximises overall sugar recoveries.

Test procedures

The objective of the investigation was to evaluate the performance of the centrifugal in terms of massecuite throughput rate, molasses production rate, sugar quality and molasses losses. The molasses production rate and the sugar quality depend on the massecuite rate. Thus the measurement of the massecuite rate had to be as accurate as possible. The optimum wash water rate was also determined by varying the wash water addition at fixed massecuite rates.

Massecuite flow measurements

Massecuite flow rates were based on the volume of massecuite processed from the crystallisers over a specified period of time. The other A-centrifugals were isolated and the BMA k2300r processed the massecuite at different feed rates by varying the feed valve position. In order to obtain steady throughput a constant massecuite supply head feeding the centrifugal was maintained. The findings (Figure 2) can be summarised as follows:

- Massecuite quality impacts on throughput achievable and the quality of sugar processed.
- Throughput and sugar quality increase with machine speed.

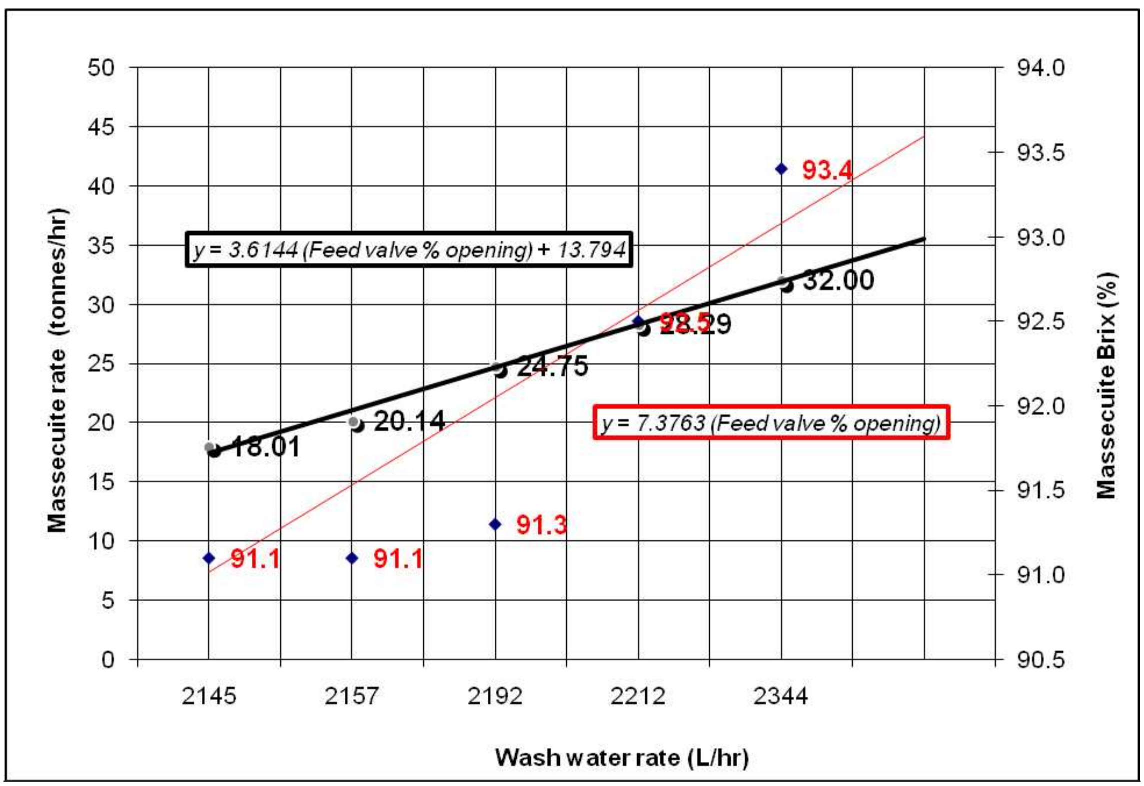

Figure 2. Relationship between massecuite throughput and massecuite feed valve (% open).

A-massecuite throughput of 32 ton/h was reached at varying wash water rates at 2156 litres per hour. At moderate wash water rates of 2098 litres per hour, massecuite throughputs of 18 ton/h were reached.

Molasses flow rate determination

Due to the difficulties (economically) and feasibility with molasses measurement and sugar flow rates these unknown rates had to be determined from steady state mass and component balances. Extensive work done by Hubbard and Love (1998) resulted in a set of conventional balances (shown in Appendix A) that can be applied when performing balances around a continuous centrifugal. Another common procedure utilised for determining a centrifugal mass balance is the Recoverable Sucrose Formula - SJM method which calculates the amount of sucrose recovered from the massecuite as sugar and then computes the massecuite throughput rate utilising a pol balance.

The molasses throughput was calculated at a steady massecuite feed to the centrifugal. The results are as summarised in Table 2.

Table 2. Molasses production rates at steady massecuite rates.

Conventional balance	Molasses production rate (ton/h)			
	Run 1	Run 2	Run 3	Average
SJM*	43.10	42.67	42.46	42.74
A1	42.81	42.68	40.60	42.03
C1	48.67	42.61	42.09	42.35
D1	42.56	42.58	41.90	42.34

*SJM = Recoverable Sucrose Formula

The molasses production rate at steady massecuite flow rates of 29 ton/h was calculated to 42 ton/h. Comparisons of the different methods of calculation are displayed in Figure 3.

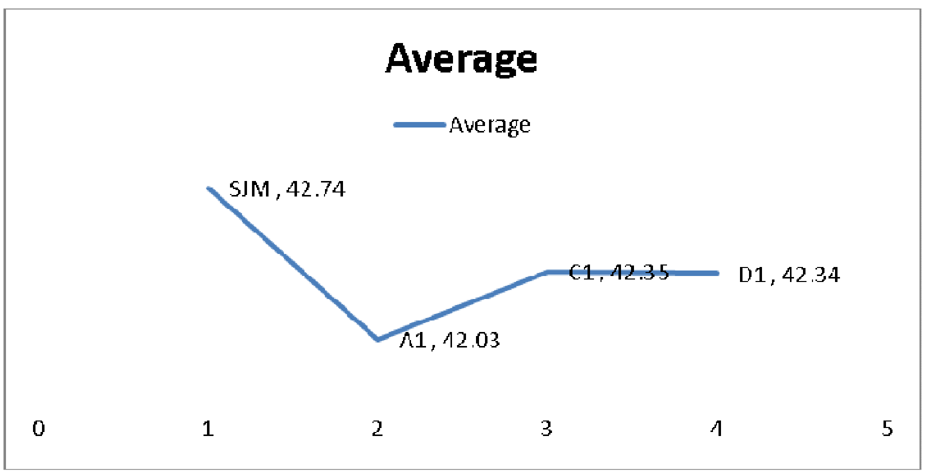

Figure 3. Comparison of mass balance types for the determination of molasses throughput.

Wash water rate to massecuite feed rate

The wash water addition has an effect on sugar purity and molasses Brix and purity rise. Thus it is important to accurately determine the correct wash water rate for the optimum operation of the centrifugal.

Best sugar quality results and purity rise are achieved by applying the correct quantities of wash water. Larger quantities of wash water addition would also result in the increase of energy consumption in order to evaporate the excess water from the pans.

A large number of tests were done with the high grade *raw* massecuite. Massecuite was fed to the centrifugal at a constant rate by maintaining a fixed valve position, while the wash water flow rate was varied.

Normal operation, according to BMA, requires 1-3% water and 1% steam on massecuite throughput (not including centrifuge cleaning or melt water). For A-massecuite the approximated wash water requirement is 6% water on massecuite throughput. It has to be considered that a fine adjustment of the centrifugal operation has to be done by applying wash water in a special ratio through the feed pipe and nozzles. The ratio depends on the massecuite quality. The recommended ratio for A-massecuite is: 70% water application on the nozzles inside the machine and 30% on the feed nozzle. The wash water flow rate was measured by two rotameters within the same calibration range. The amount of water added was controlled by the centrifugal's Programmable Logic Controller by adjusting the valve position of the wash water.

Figure 4 illustrates results from a large number of tests done with low purity raw massecuites and clearly shows the benefits of wash water application (www.BMA.com, accessed 01 November 2009).

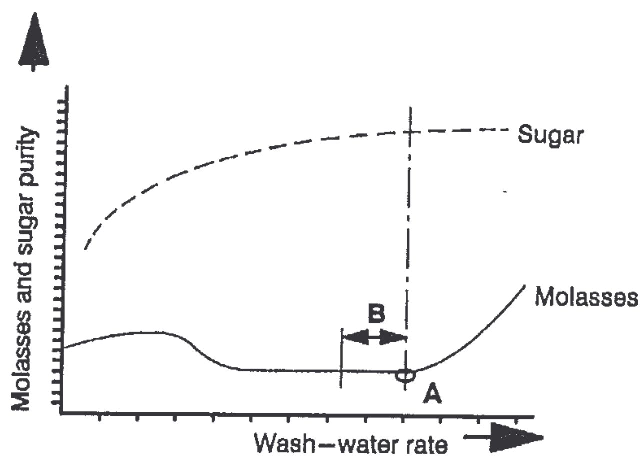

Figure 4. Relationship purity to wash water application.

It is evident from the diagram that the molasses purity goes up when a small amount of water is added. Experience shows that the molasses purity drops to an optimum level for the massecuite concerned as the amount of wash water added is increased. This level remains the same until too much water starts to partially dissolve the sugar crystals. The optimum point in the diagram (end of optimum point B), should be established by trial and error method, and the addition of water can be reduced, for safety reasons, by quantity B (www.BMA.com, accessed 01 November 2009).

The wash water results obtained at steady massecuite throughput (for massecuite feed rates of 29 ton/h) at varying wash water flow rates is given in Figure 5. The effect on sugar quality was noted and each experiment lasted for 30 minutes.

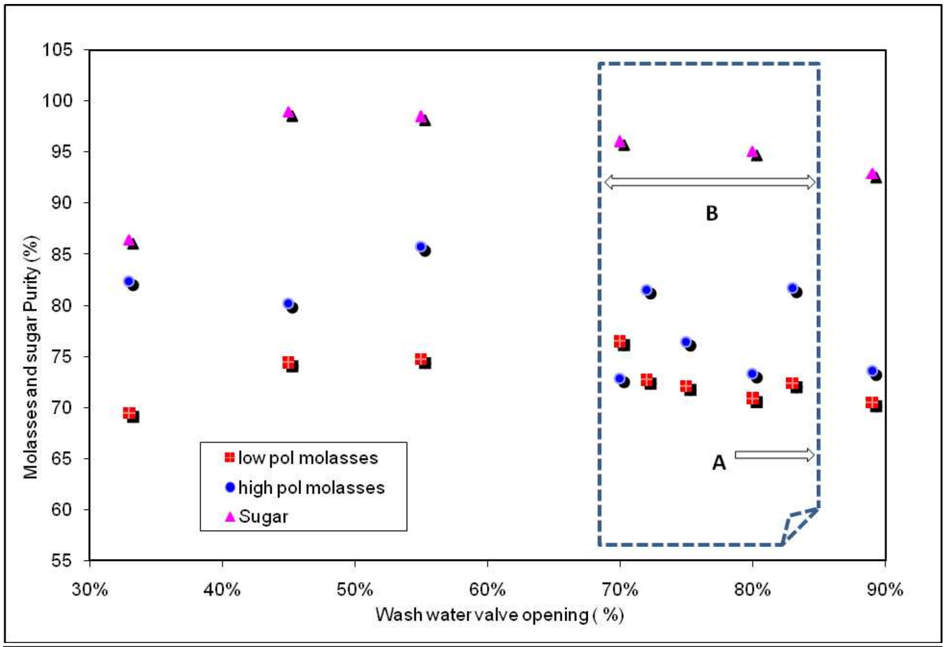

Figure 5. Relationship between sugar purity and molasses purity at varying wash water rates.

It was observed that the purity rise across the machine went up slightly when a small amount of wash water of about 50 L/h was added. The molasses purities dropped slightly to an optimum level as the amount of wash water was increased. The molasses purities stayed the same until too much water caused dissolution of the sugar crystals (beyond point B on the graph). By trial and error the optimum point, before dissolution of the crystals occurs, was determined.

The effect on the sugar quality cured by the BMA k2300r continuous machine is shown in Table 3 (values with region B and at point A in Figure 5).

Table 3. Effect of wash water rate on sugar quality cured by the continuous centrifugal.

Wash water application		Melting medium (t/h)	Massecuite flow rate (t/h)	Total wash water (C) to m/c flow (%)
Valve position (%)	Curing water (t/h)			
80.00%	2.340	11.000	29.000	8.20%
75.00%	2.190	11.000	29.000	7.55%
72.00%	2.180	11.000	29.000	7.52%

It was observed that, at the varying wash water rates of 6.50, 7.50 and 8.20% on massecuite feed rate, the molasses purity rise across the machine was within the acceptable ranges (<2.50).

Figure 6 shows the relationship between the purity rise and the wash water % massecuite for the continuous machine. The plot shows that the molasses purity rise tends to increase with wash % massecuite. This is expected as the increasing wash water rates lead to higher levels of purity rise.

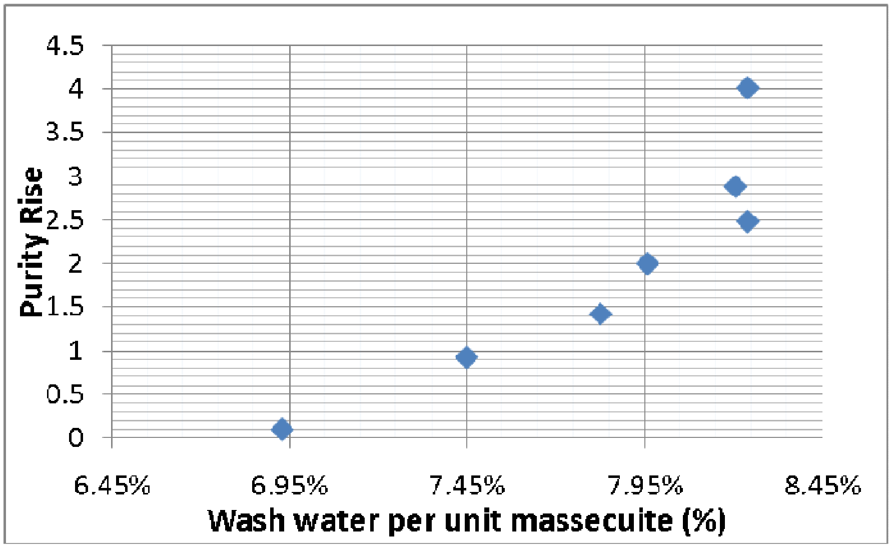

Figure 6. Purity rise as a function of wash % massecuite.

Lower purity rises will lead to good exhaustion of the A-massecuite and lower target purity differences (TPDs) for the raw house. Higher purity rises will lead to poor exhaustion of the A-massecuite, higher TPDs and increased steam consumption due to excessive washing (Figure 7).

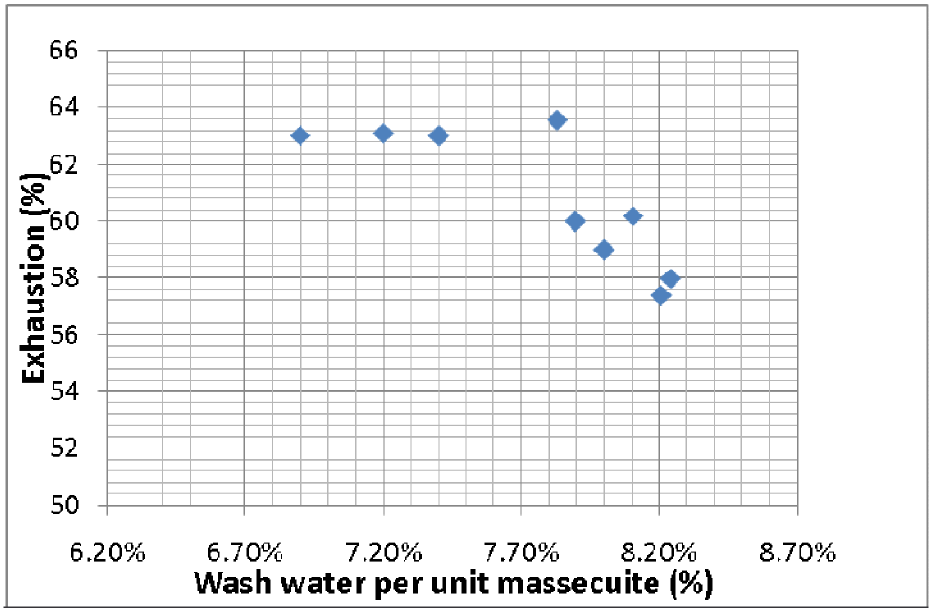

Figure 7. A-exhaustion as a function of wash % massecuite.

Sugar quality

The massecuite quality has a major influence on the final sugar quality, and the performance of any centrifugal is dependent on the material that is being fed to it. Figure 8 shows that the average ICUMSA colour of the product sugar for the continuous machine at 6.0% to 6.50% wash water to massecuite flow is 930 ICUMSA units (IU).

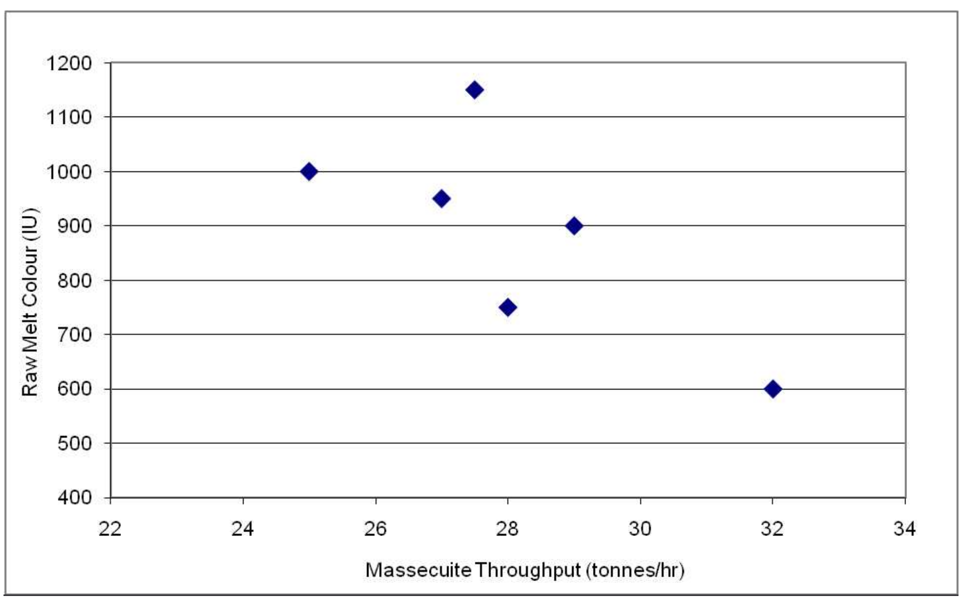

Figure 8. Melt colours at different massecuite throughput.

Sugar purities are shown graphically in Figure 9 for the different tests that were carried out around the centrifugal. At the higher wash water rate of 7.50% the ICUMSA colour of the sugar produced was lower.

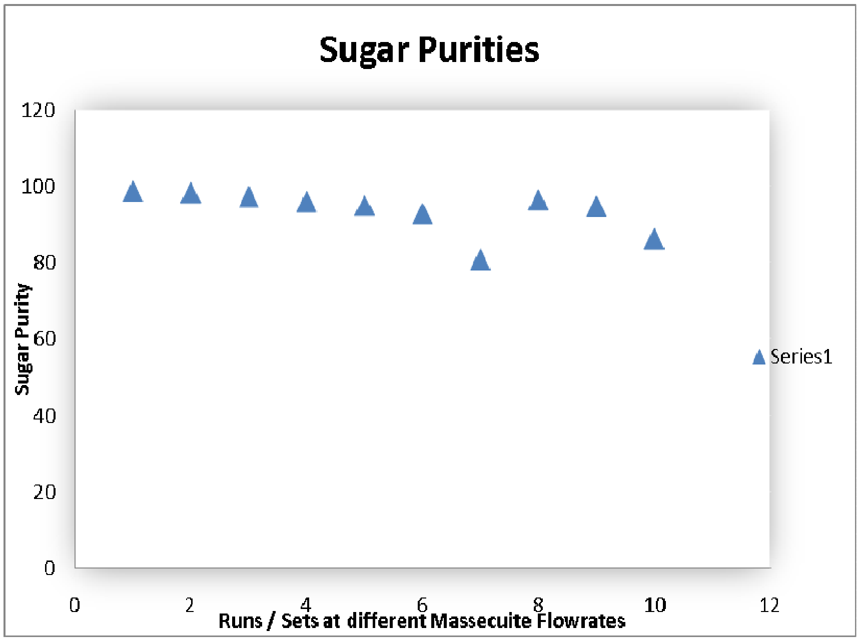

Figure 9. Sugar purities at different massecuite rates.

The most important parameter in the evaulation of the continous centrifugal is the sugar quality that is produced.

Molasses classification benefits

The Illovo Pty Limited current specification for refined sugar colour is 45 IU. The Ubombo refinery can only remove a certain percentage of colours from the raw material. It is therefore necessary to raise the quality of the raw input to achieve a better refined sugar colour.

The installation of the machine allows the optimisation of the amount of wash water into the centrifugal in order to achieve lower sugar colours at optimum A-exhaustion rates.

The benefits of A-molasses classification is that the production of the lower purity molasses favourably affects the factory's downstream purity profile. A lower purity B-molasses would require a smaller amount of A-molasses footing to produce C-massecuite of 52.08%. This lower C-massecuite would require an exhaustion of only 49 to achieve a 0.50 unit improvement in final molasses purity. Thus a high Boiling House Recovery (BHR) is achievable.

Crystal breakage

Since the continuous centrifugal provides A-sugar for the refinery, the crystal breakage analysis was not carried out as all the crystals are remelted in the refinery melter.

Power consumption

The advantages of continuous centrifugal operation, in terms of energy savings, are well known (Journet and Thelwall, 2001). A trend of power consumption as a function of massecuite feed is presented in Figure 10.

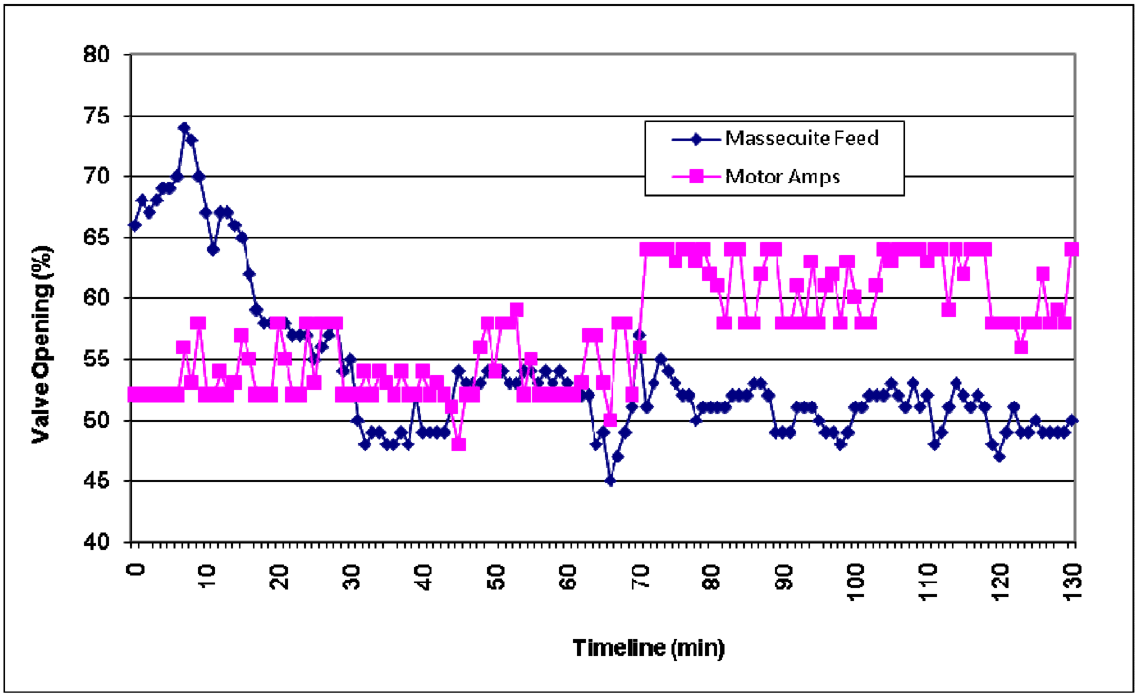

Figure 10. Massecuite feed rate as a function of power consumption (motor Amperage).

As the massecuite rate changes (increase or decrease), the continuous centrifugal power consumption change accordingly, which resulted in optimised power consumption.

Comparison to manufacturer's specifications

Table 4 shows a comparative analysis of the experimental data against the manufacturer's technical specifications. The BMA k2300r continuous centrifugal met the manufacturer's specifications.

Table 4. Comparison of evaluated values against the manufacturer's specifications.

	Manufacturer specification	Plant data	Units of measurement
Massecuite throughput	32	18 – 32	Ton/h
Melt Brix	65	62 – 65	
Wash water	6 – 8	6.50 – 7.50	% to Mcte
Molasses throughput	–	42	Ton/h
A-exhaustion	–	63	
Purity rise	–	2.0 – 2.5	

Future developments

Numerous aspects of the high grade continuous machines still need to be investigated. One of these is the application of different screens, with different open areas and different materials of construction. Foreign material in the A-crystallisers can adversely affect the screen life cycle. This is an area that still needs to be investigated in order to minimise screen failures. A screen management programme (SMP) should be considered as proposed by Ninela and Rajoo (2006).

Conclusions

The high grade continuous centrifugal at Ubombo has proved capable of processing A-massecuite successfully and producing good quality sugar for the back-end refinery. The capacity of the A-centrifugal station was increased from about 95 to 127 ton/h. At the various water usages of 6.5, 7.2 and 7.5% on massecuite feed rate, minimum molasses purity rises (<2.50) were achieved at steady massecuite feed rates. The power requirement for the A-centrifugal station was reduced due to the proportionally varying electrical load with the massecuite feed rate. The machine fully satisfied the supplier specifications.

The four benefits of this exercise were:

- Thorough understanding of the Ubombo A-curing station and its maximum operational limits.
- Clear justification for continued capital investment in centrifugal replacement.
- Use of the experience for the improved automation of the continuous BMA k2300r centrifugal.
- Proper 'Technical Operational Practices' to achieve highly efficient station operation.

The main advantages for the BMA k2300r are as listed below:

- Steady power consumption. The continuous machine requires 0.9 kW/ton/h consumption at full capacity.
- Lower capital cost and installation due to simpler design.
- Lower maintenance costs. The machine design is less complicated, requires less attention, less man power, and only scheduled maintenance on screens and predictive maintenance on bearings.
- Simple operability.
- Lower rate of dissolving sugar per unit of wash water. The sugar wall in the basket is much thinner, resulting in less time available for dissolving sugar off the crystal.

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Appendix A
Mass balances for determining the massecuite feed rate to a continuous centrifugal.

Balance A1: Brix balance using molasses and wash water flow rates

$$Tons_{M/C} \equiv -Tons_{mol}\left(1-\frac{B_{xmol}}{(100-moisture)}\right)-Tons_{H2O} \div \left(1-\frac{B_{xM/C}}{(100-moisture)}\right)$$

Balance B1: Combined brix and non-pol solids balance using wash water

$$Tons_{M/C} \equiv \frac{Tons_{H2O}}{\left(\frac{NP\%_{M/C}}{NP\%_{mol}}\right)\left(1-\frac{Bx_{mol}}{100-moisture}\right)-\left(1-\frac{Bx_{M/C}}{(100-moisture)}\right)}$$

Balance C1: Non-pol solids balance using molasses rate

$$Tons_{M/C} \equiv Tons_{mol}\left(\frac{NP\%mol}{NP\%_{M/C}}\right)$$

Balance D1: Non-pol solids balance including non-pol in sugar

$$Tons_{M/C} \equiv \frac{Tons_{H2O}\left(Bx_{sug}-Pol_{sug}\right)+Tons_{mol}\left(Bx_{mol}-Pol_{mol}-Bx_{sugatr}+Pol_{sugar}\right)}{\left(Bx_{M/C}-Pol_{M/C}-Bx_{sugar}+Pol_{sugar}\right)}$$

Sugar Juice Molasses (SJM) Formula:

$$SJM\ \ recovery \equiv \frac{sugar\ \ purity\ \left(m/c_{purity}-mol_{pty}\right)}{m/c_{purity}\left(sugar\ \ purity-mol\ \ purity\right)} * 100\%$$

$$Tons\ \ pol\ in\ m/c \equiv \frac{Tons_{pol} * pol\%mol}{100-SJM_{recovery}}$$

$$Tons\ m/c \equiv \frac{Tons\ \ pol\ in\ m/c}{pol\%\ m/c} * 100$$